INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

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EXPERIMENTAL WORKSHOP ON
HIGH TEMPERATURE SUPERCONDUCTORS
(11 - 22 April 1988)

HIGH FIELD APPLICATIONS OF SUPERCONDUCTIVITY

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Points to outline:

If superconductivity can be applied for "electrotechnical machinery" (i.e. exploiting zero resistance)

Then the main advantages are

1) Higher specific power
2) Overcoming technical limits due to thermal dissipation
3) (Marginally) power saving (except in long distance transmission)

Difficulties:

- High magnetomotive forces: limit to usable fields (≃ 15÷20 Tesla)
- Multifilamentary windings for current distribution
- Thermal properties (probably "sluggish")
- Working temperature should be 0.5÷0.8 T_c so this should be Kept in mind thinking to type of superconductor and working refrigeration.

Confronto tra tecnologie normali e tecnologie superconduttive negli avvolgimenti di campo (Rame o Alluminio vs superconduttore)

	Rame	Superconduttore
DENSITA' di CORRENTE A/cm^2	$\lesssim$ 1000	10 000 ÷ 1000 000
TEMPERATURE LAVORO °C	< 150	-272 → 183
REFRIGERANTI	aria, gas, acqua	elio—azoto (liquidi)
CAMPI MAGNETICI MAX (Tesla)	~ 2, con ferro	~ 25-30, limite meccanico
DISSIPAZIONE a 2 Tesla	Kw x m^3 di traferro	~ 10 W x m^3 di campo
"" a 3 Tesla	Mw ""	~ 10 W ""
"" campi maggiori	$(campo)^2$	~ costante

Quindi: Risparmio energia
maggiori potenze specifiche
diventano possibili: MHD – Fusione – Acceleratori –
– Levitazione ...

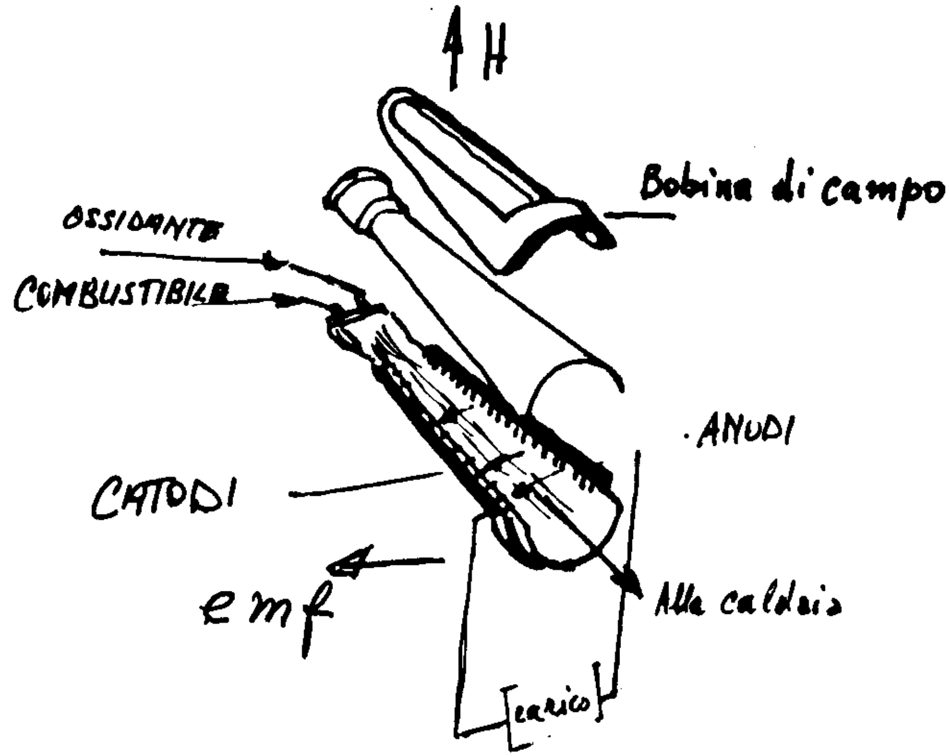
APPLICAZIONI DELLE PROPRIETA'ELETTRICHE

GENERAZIONE DI CAMPI MAGNETICI INTENSI:
- UNIFORMI PER RISONANZA MAGNETICA NUCLEARE
- INTENSI PER FISICA DELLA MATERIA
- MULTIPOLARI O SPAZIALMENTE MODULATI PER ACCELERATORI
- "SOTTILI" E DI GRANDE VOLUME PER FISICA NUCLEARE
- TOROIDALI O A SPECCHIO PER FUSIONE TERMONUCLEARE
- DIPOLARI PER MHD:CONVERSIONE DIRETTA,PROPULSIONE,POMPE
- PIANI O A SELLA PER LEVITAZIONE MECCANICA
- SOLENOIDALI PER ACCUMULO DI ENERGIA ELETTRICA
- A FORTI GRADIENTI PER SEPARAZIONE/PURIFICAZIONE

APPLICAZIONI IN MACCHINE:
- TRASFORMATORI AC E DC
- LIMITATORI DI POTENZA
- TURBOALTERNATORI
- MOTORI/GENERATORI DC,CONVERTITORI DI COPPIA MECCANICA
- POMPE DI FLUSSO MAGNETICO

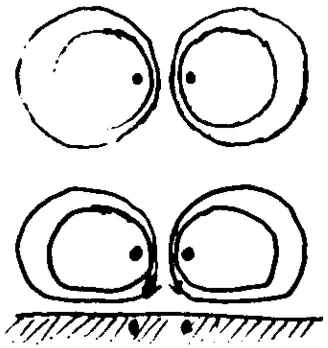
APPLICAZIONI IN BASSO CAMPO:
- CAVI PER TRASPORTO DI ENERGIA ELETTRICA
- CAVITA'RISONANTI
- SCHERMI ELETTROMAGNETICI
- COMPARATORI DC
- SENSORI BOLOMETRICI - TERMOMETRI
- SUPPORTI E COLLEGAMENTI PER MICROCIRCUITI

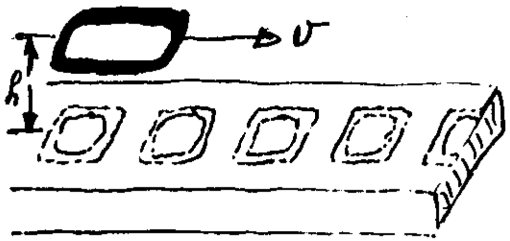
MHD



Lunghezza ~ 6 m ÷ 10 m.
larghezza 1 ÷ 3 m
Campo ~ 6 Tesla

Probl: materiali e isolamenti anodi





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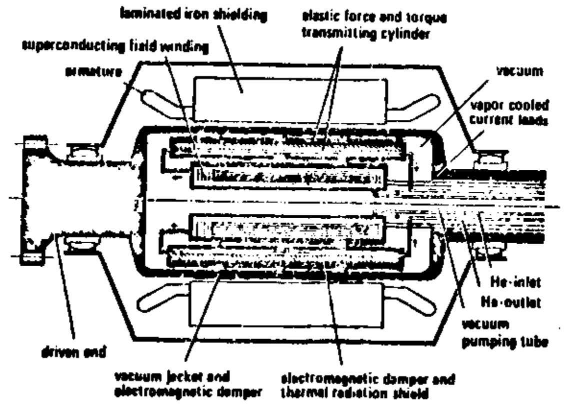


Fig. 66 Schematic of a superconducting generator.

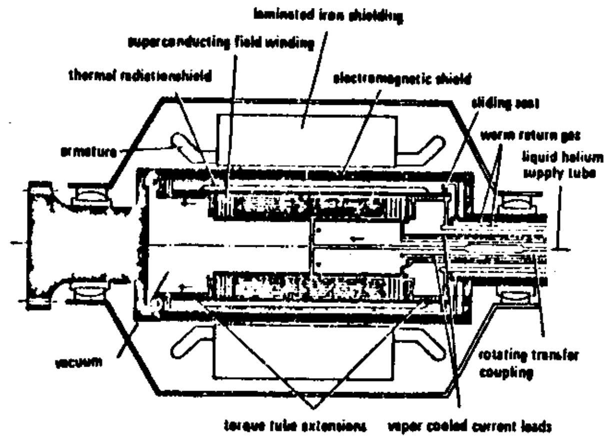


Fig. 67 Schematic of a superconducting generator.

COMMON PHYSICAL DATA FOR CRYOGENIC FLUIDS

Substance	Density: Gas (NTP)* g/l	Density: Gas (NTP)* lbs/ft.^{3}	Density: Liquid (NBP)† g/l	Density: Liquid (NBP)† lbs/ft.^{3}	Volume Ratio Gas (NTP) / Liquid (NBP)	Heat of Vaporization cal/g	Heat of Vaporization Btu/lb
He^4	0.1785	0.01114	125	7.8	700.3	4 9	8.7
H_2	0.08988	0.005611	71	4.4	789.9	108.0	194.5
N_2	1.251	0.07807	808	50.4	645.9	47.6	85.7
Ne	0.8999	0.05618	1207	75.4	1341.1	20.5	36.9
F_2	1.696	0.1059	1510	94.3	890.0	41.2	74.1
Ar	1.784	0.1114	1400	87.4	784.0	39.0	70.2
O_2	1.429	0.08921	1142	71.3	799.2	50.9	91.6
CH_4	0.7168	0.04475	415	26.6	578.0	121.9	219.2

*NTP is 0°C, 760 mm   †NBP is Normal Boiling Point at 760 mm

1 Kg = 2.205 lbs
1 lb = 453.6 gms

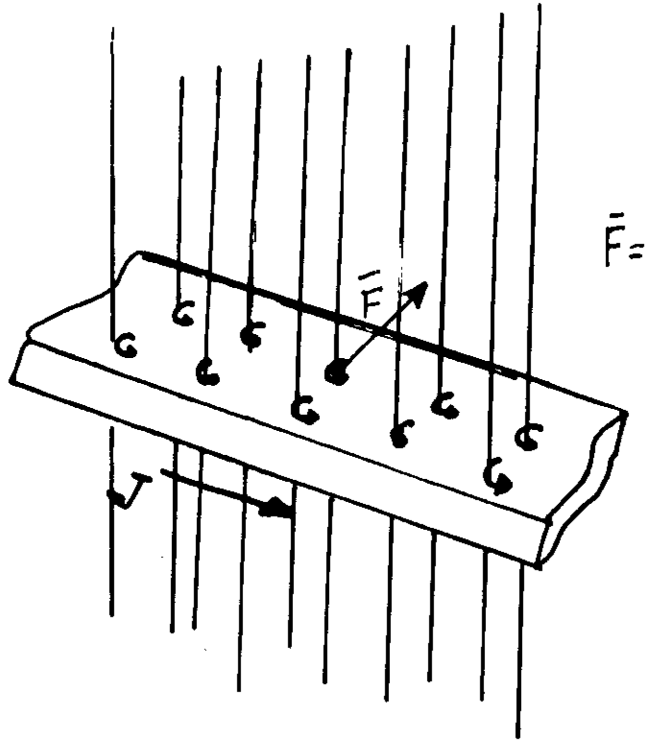
1 liter = 0.03531 cu ft = 0.2642 gal
1 cu ft = 28.32 liters = 7.481 gal
1 gal = 0.1337 cu ft = 3.785 liters

1 cal = 0.003968 Btu
1 Btu = 252 cal

BOILING POINTS OF GASES

Substance B.P. (approx.) at 1 Atmosphere		°C	°F	°K
Helium	He_3	−269.9	−453.8	3.2
Helium	He_4	−268.9	−452.0	4.2
Hydrogen	H_2	−252.8	−423.0	20.3
Deuterium	D_2	−249.5	−417.1	23.6
Tritium	T_2	−248.1	−414.6	25.0
Neon	Ne	−246.0	−410.8	27.1
Nitrogen	N_2	−195.8	−320.4	77.3
Carbon Monoxide	CO	−191.5	−312.7	81.6
Fluorine	F_2	−188.1	−306.6	85.0
Argon	Ar	−185.9	−302.6	87.2
Oxygen	O_2	−183.0	−297.4	90.1
Methane	CH_4	−161.5	−258.7	111.6
Krypton	Kr	−153.4	−244.1	119.7
Ozone	O_3	−111.9	−169.4	161.3
Xenon	Xe	−108.1	−162.6	165.0
Ethylene	C_2H_4	−103.7	−154.7	169.4
Ethane	C_2H_6	− 88.6	−127.5	184.5
Nitrous Oxide	N_2O	− 88.5	−127.3	184.6
Acetylene	C_2H_2*	− 84.0	−119.2	189.1
Carbon Dioxide	CO_2*	− 78.5	−109.3	194.6
Ketene	C_2H_2O	− 56.0	− 68.8	217.1
Propylene	C_3H_6	− 47.7	− 53.9	225.4
Propane	C_3H_8	− 42.1	− 43.8	231.0
$Freon_{22}$	$CHClF_2$	− 40.8	− 41.4	232.3
Ammonia	NH_3	− 33.4	− 28.1	239.7
$Freon_{12}$	CCl_2F_2	− 30.5	− 22.9	242.6
Methyl Chloride	CH_3Cl	− 24.1	− 11.4	249.0
Isobutane	$(CH_3)_2C_2H_4$	− 11.7	+ 10.9	261.4
Sulphur Dioxide	SO_2	− 10.0	14.0	263.1
Butane	C_4H_{10}	− 0.5	31.1	272.6
Methyl Bromide	CH_3Br	+ 3.5	38.3	276.6
Ethyl Chloride	C_2H_5Cl	12.3	54.1	285.4
Carbon Disulfide	CS_2	46.3	115.3	319.4
Carbon Tetra'ride	CCl_4	76.7	170.1	349.8
* Sublimes				

(1) 0°K = −273.1°C   (2) °F = 9/5(°C) + 32.0



$\bar{F}$ = forza di Lorentz

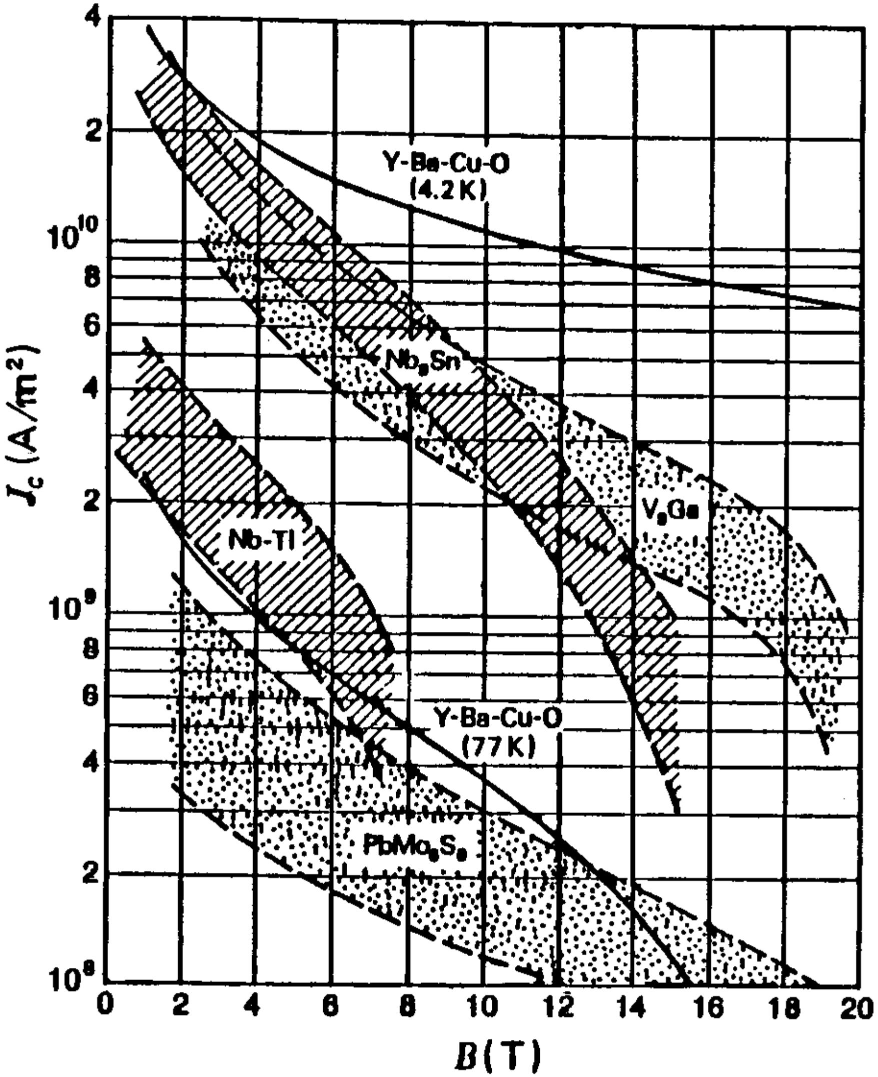


Fig. 2

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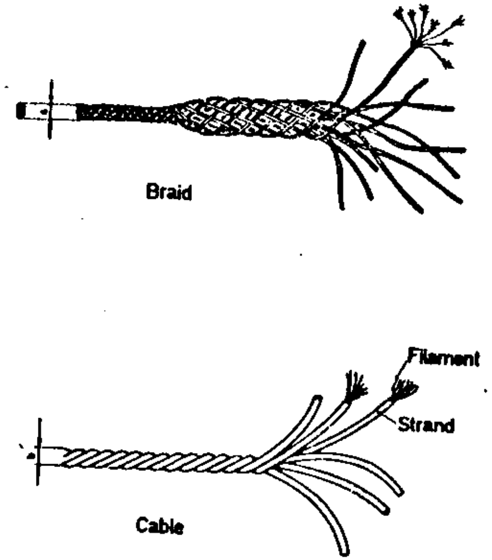

Fig. 37. Conductor Configurations Used in Pulsed Magnets. Strands are transposed into a braid and into a cable.

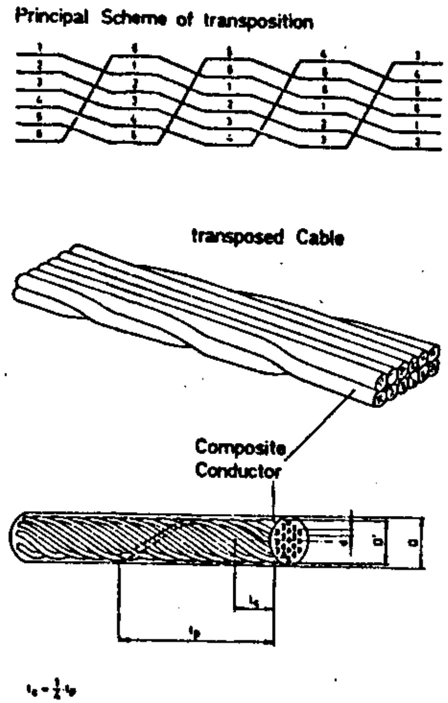

Fig. 38. Fully Transposed Cable. A single composite conductor (strand) with twisted filaments is shown at the bottom.

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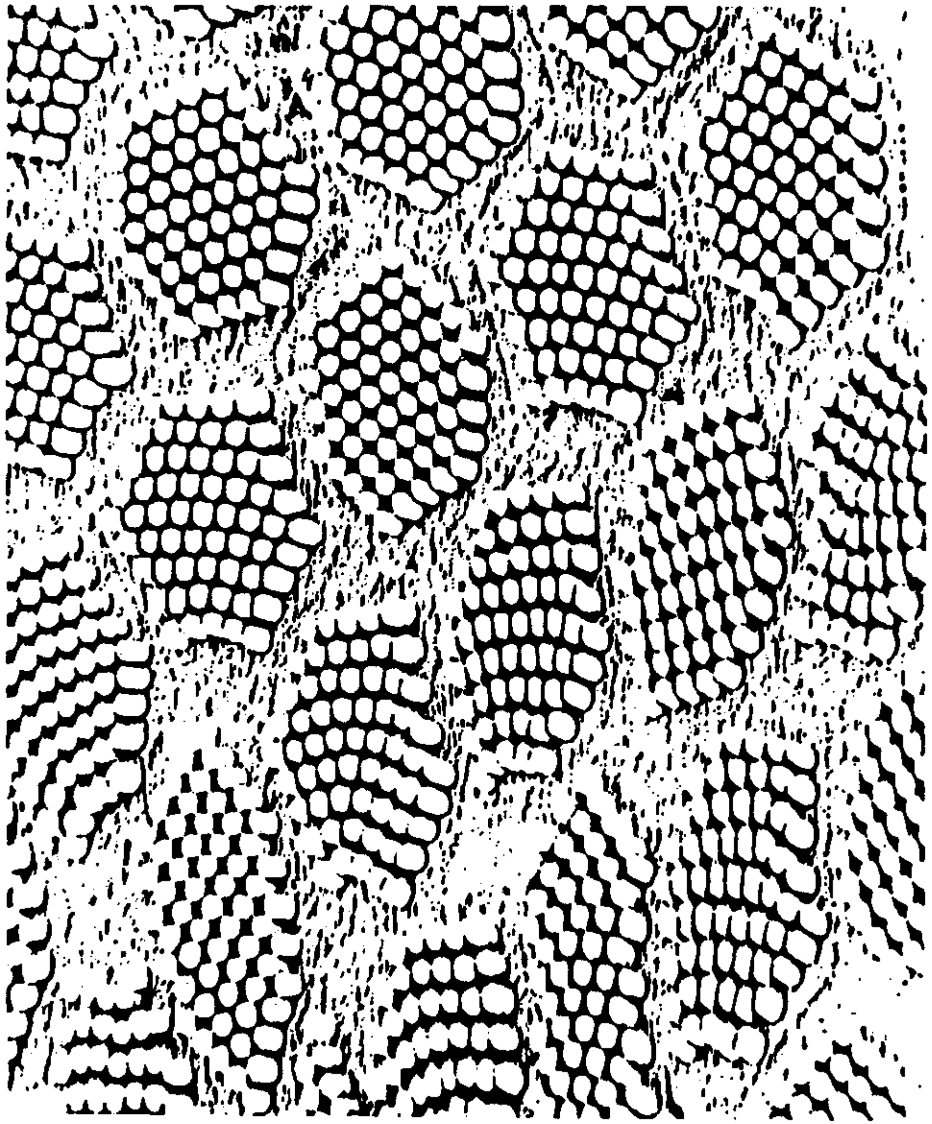

Projected Implementation Times For Various Superconducting Devices

(Based on Interviews with three leading Japanese researchers.)

Application	K. Tachikawa (Tokai U.)	S. Tanaka (U. Tokyo)	M. Makino (Mitsubishi Res.)
Magnetic levitated train	-2000	1995-2000	1995-2000
S.C.-driven ship	-2000	-1997	1990-1995
Power line	1995-2000	-2000	-2000
Power generate	-2000	-2000	1995-2000
Power storage	-2000	-2000	1990-1995
Josephson device	-1990	1990-1995	-1990
IC package/ substrate	-1990	1990-1995	1990-1995
S.C. semicon. IC	-1990	1990-1995	-1990
Magnetic sensors	-1990	1995-2000	-1990
IR sensors	-1990	1990-1995	-1990
NMR-CT	1990-1995	1990-1995	-1990
Magnetic shielding	1990-1995	now	1990-1995
Toys or kits	1990-1995	-1990	1990-1995
S.C. magnet (fusion)	-2000	-1995	1990-1995

Source: Nippon Keizai Shimbun (May 18, 1987)

Valutazione del mercato mondiale dei superconduttori

Utilizzo finale:	M$ (1986)	M$ (2005)
Elettronica	40	400
Strumentazione e biomedica	200	780
Aerospazio e difesa	25	350
Industriale	20	200
Generazione energia	<5	50
Trasporti	<5	20
Totali	290	1800

(Da Strategic Analysis Inc.)

APPLICATION PROFILES

ELECTRONICS

- Transistors
- IC packages and substrates
- Josephson junction devices

AEROSPACE AND DEFENSE

- Rail guns
- Electromagnetic unmanned launch space vehicles
- Microwave power transmission
- Communications
- Gyroscopes

TRANSPORTATION

- Magnetic levitated vehicles
- Marine propulsion
- High-speed propulsion

POWER GENERATION

- Motors and generators
- Energy storage
- Transmission
- Fusion
- Magnetic hydrodynamics (MHD)

INDUSTRIAL

- Separation
- Processing of materials
- Sensors and transducers
- Magnetic shielding
- Magnets

INSTRUMENTATION AND CONTROL

- Nuclear magnetic resonance diagnostic systems (NMR)
- Particle accelerators
- Biotechnology and engineering

SOURCE: STRATEGIC ANALYSIS INC.

B. Iniziative del presidente USA del 28-29 luglio 1987

THE WHITE HOUSE

Office of the Press Secretary

July 28, 1987

The President's Superconductivity Initiative

Fact Sheet

The President has announced an eleven-point initiative to promote further work in the field of superconductivity and ensure U.S. readiness in commercializing technologies resulting from recent and anticipated scientific advances.

The U.S. has been a leader for years in the field of superconductivity - the phenomenon of conducting electricity without resistance. U.S. private and Government researchers have also been at the forefront of recent laboratory discoveries allowing superconductivity to occur at higher temperatures and with greater current-carrying capacity than was previously possible.

The Federal Government has played a key role in these developments through the funding of basic research. The National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) both provided funding for Dr. Paul Chu at the University of Houston in his landmark efforts in raising the temperature at which superconductivity occurs. In addition, the Department of Energy (DOE), which is the principal Federal supporter in the field of superconductivity, has been a leader in the search for the mechanism that produces high-temperature superconductivity and in research into the practical uses of these new materials. The Federal Government is currently spending approximately U.S.$ 55 million in superconductivity research, with more than one-half of that reallocated within the last six months.

The President's initiative reflects his belief that it is critical that the U.S. translate our leadership in science into leadership in commerce. While the U.S. private sector must take the lead, the Administration is taking important actions to facilitate and speed the process, including increasing funding for basic research and removing impediments to precompetitive collaboration on generic research and production and to the swift transfer of technology and technical information from the Government to the private sector.

The President's Superconductivity Initiative has three objectives:

1. Promoting greater-cooperation among the Federal Government, academia - and U.S. industry in the basic and enabling research that is necessary to continue scientific breakthroughs in superconductivity;

2. Enabling the U.S. private sector to convert more rapidly scientific advances into new and improved products and processes, and

3. Better protecting the intellectual property rights of scientists, engineers, and businessmen working in superconductivity.

The Superconductivity Initiative includes both legislative and administrative proposals. The former will be forwarded in a single bill. The major components of the initiative are:

Legislative

1. Amending the National Cooperative Research Act (NCRA) to expand the concept of a permissible joint venture to include some types of joint production ventures. This is a particularly important step that would ease the risk of antitrust litigation perceived by U.S. business that could otherwise benefit from precompetitive joint ventures. If enacted, it could benefit from precompetitive joint ventures. If enacted, it developments using superconductivity, but other high technology products as well.

2. Amending U.S. patent laws to increase protection for manufacturing process patents. This would enable U.S. owners of process patents to obtain damages for infringement where products made with those processes are imported into the U.S.

3. Authorizing Federal agencies to withold from release under the Freedom of Information Act (FOIA) commercially valuable scientific and technical information generated in Government owned and operated laboratories that, if released, will harm U.S. economic competitiveness.

Administrative

4. Establishing a "Wise Men" Advisory Group on Superconductivity under the auspices of the White House Science Council. This would be a small group of three to five people from industry and academia that would advise the Administration on research and commercialization policies.

5. Establishing a number of "Superconductivity Research Centers" (SRCs) and other similar groups that would: (1) conduct important basic research in superconductivity; and (2) serve as repositories of information to be disseminated throughout the scientific community.

a. The Department of Energy will establish three SRCs, as well as a computer data base: Center for Superconductivity Applications at the Argonne National Laboratory;

- Center for thin Film Applications at the Lawrence Berkely Laboratory
- Center for Basic Scientific Information at the Ames Laboratory;
- Computer Data Base on Supeconductivity of the DOE Office of Scientific & Technology Information.

b. The Department of Commerce (DOC) will establish a Superconductivity Center at the National Bureau of Standards (NBS) Laboratory in Boulder, Colorado. The center will focus on electronic applications of high temperature superconductivity.

c. The National Aeronautic and Space Administration (NASA) is establishing a coordinating group on superconductivity activities at its office of Aeronautics and Space Technology.

d. NSF will provide support for research in high temperature superconductivity programs a three of its materials research laboratories. In addition, NSF is initiating a series of "quick start" grants for research into processing superconducting materials into useful forms including wire, rods, tubes, films, and ribbons.

e. The Department of Defense is developing a multi-year plan to ensure use of superconductivity technologies in military systems as soon as possible. DoD will spend nearly U.S.$. 150 million over three years.

DoD will build upon its long experience in superconductivity R & D to systematically: define the engineering parameters for high-temperature superconducting materials; develop the required processing and manufacturing capabilities; and accomplish the necessary development, engineering, and operational prototype testing of superconductors.

Small scale applications with commercial spin-off potential include sensors and electronics. Potential large-scale applications include compact, high-efficiency electric ship drive; electrical energy storage; pulsed power systems; and free electron lasers.

6. Urging all Federal agencies to implement quickly the steps outlined in Executive Order 12591 designed to: (1) transfer technology developed in Federal Laboratories into the provate sector; and (2) encourage Federal, university, and industry cooperation in research. The White House Science Advisor will report to the President by December 1, 1987 on progress in implementing the Executive Order, particularly with regards to superconductivity.

7. Directing the Patent and Trademark Office to accelerate the proprocessing of patent applications and adjudication of disputes involving superconductivity technologies when requested by the applicants to do so.

8. Directing the NBS to accelerate its efforts to develop and coordinate common standards (e.g. measurement methods, standard reference materials, and supporting technical data) in the U.S. and internationally for superconductors and related devices.

9. Encouraging Federal Agencies to continue to reallocate FY 1987 funds into superconductivity basic research, applied research in enabling technologies, and prototype development. Agencies are directed to place a high priority for this area in FY 1988 funding and FY 1989 planning.

10. Requesting that Dod accelerate prototype work in sensor, electronic, and superconducting magnet-based military applications and that the Department of Commerce accelerate development of prototype devices in detection and measurement of weak magnetic fields.

11. Taking advantage of the opportunity presented by the current negociations for renewing the U.S. - Japan Agreement on Science and Technology to seek reciprocal U.S. opportunities to participate in Japanese government supported research and development, including superconductivity.

In April, The President issued Executive Order 12591 Faciliting Access to Science and Technology directed at encouraging increased commercialization of the U.S. science and technology enterprise.